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PACKAGING SYSTEM WITH OXYGEN SENSOR

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/437,624, filed December 31, 2002, incorporated herein in its entirety by reference.

FIELD OF THE INVENTION

The present invention relates to the field of packaging of sterile or oxygen sensitive products, such as medical devices and food products. More particularly, the present invention is directed to methods and devices for packaging oxygen sensitive items with a material that visually indicates the presence of oxygen inside the packaging.

BACKGROUND OF THE INVENTION

In certain applications, such as pharmaceutical storage or food processing, it is desirable to package the product in a controlled atmosphere to ensure freshness, proper chemical activity, or to prevent microbial contamination. The controlled atmosphere can be an inert gas such as nitrogen or carbon dioxide, however, it could also be a Nobel gas. In some applications, the controlled environment could also be a vacuum. In these applications where a controlled atmosphere is desirable, it may be beneficial to be able to determine that the desired inert or controlled atmosphere has not been compromised. The presence of oxygen in a previously evacuated sample indicates atmospheric penetration has occurred and that the controlled

atmosphere has been compromised. Thus, oxygen detection is one method for determining if a controlled atmosphere has been breeched.

In the medical and food processing industries, it may be desirable to sterilize the medical and food products after these products have been placed inside containers with controlled environments. The medical and food processing industries have sterilized some appropriate products with gamma radiation. Gamma radiation, which can be derived from Cobalt 60, is lethal to bacteria and other micro-organisms due to the effect the radiation has on living cells. In addition, gamma radiation can also be detrimental to some chemical systems and compositions. The dose or amount of radiation absorbed is typically measured in either Megarads or Kilograys, where 1 Megarad is equivalent to 10 Kilograys. In general, a 2.5 Megarad, or 25 Kilogray, dose of gamma radiation can be sufficient to kill most microorganisms.

Gamma radiation is composed of high energy photons with wavelengths generally shorter than about 0.1 nm. Gamma radiation is emitted from atomic nuclei during radioactive decay and generally follows the ejection of beta rays from the nucleus. X-rays are similar to gamma rays in the sense that both are highly energetic and penetrating forms of radiation. However, gamma rays usually have shorter wavelengths than x-rays, and as a result gamma rays are slightly higher in energy than x-rays.

As a result of the increased use of gamma radiation sterilization and packaging in controlled environments, there is a need for oxygen sensitive materials that can be placed inside medical and food product containers which can detect the presence of oxygen after the container has been irradiated, and possibly sterilized, with gamma radiation.

Currently, there are several types of oxygen, and oxidation, sensors designed to be used in packaging applications. See, for example, U.S. Patent No. 4,526,752 to Perlman et al., U.S. Patent No. 5,096,813 to Krumhar, U.S. Patent No. 6,399,387 to Stenhom et al., and U.S. Patent No. 6,325,974 to Ahvenainen et al. However, none of these patents are directed towards oxygen sensitive materials that are activated by radiation. Furthermore, the above-mentioned sensors are not suitable to form component parts for other devices. With the volume of medical devices and food products being produced, it would be desirable to provide an oxygen sensor that was easily stored in oxygen rich environments and could be activated upon exposure to gamma radiation in the absence of oxygen.

SUMMARY OF THE INVENTION

In some embodiments, the present invention is directed toward a method and apparatus for providing an oxygen sensitive container that is suitable for detecting the presence of oxygen inside the container after the container has been irradiated with radiation. In addition, at least some of the oxygen sensitive material of the present invention can be incorporated into component parts for some other devices, such as medical devices. By using the oxygen sensitive material as a component piece of a medical device, or other device, the device itself becomes an oxygen indicator, thereby removing any ambiguity regarding the contact of the device with the ambient atmosphere. Furthermore, some of the oxygen sensitive materials of the present invention can be stored in oxygen rich environments, because they do not become "active" until the oxygen sensor material has been exposed to radiation. In some embodiments, the oxygen sensitive materials are activated in an oxygen-free environment. As used in this application, the

term "activated" or "active" means that the oxygen sensitive material will undergo a visual change when exposed to oxygen. Thus, the present invention creates an effective storage device for detecting the presence of oxygen, and ultimately for determining a failure in packaging, in applications involving radiation sterilization.

In one embodiment of the present invention, a sealable container adapted to isolate the contents of the container form the ambient atmosphere is provided with an oxygen sensitive material located within the sealable container. The oxygen sensitive material can be any material that undergoes a visual change when in contact with oxygen after the oxygen sensitive material, or composition, has been irradiated with gamma radiation in an oxygen free environment.

In another embodiment of the present invention, a medical device is provided that contains a structural element which is composed of an oxygen sensitive polymeric composition. The oxygen sensitive polymeric composition will visually indicate if the medical device has been exposed to oxygen. Thus, in this embodiment of the present invention the product, i.e., the medical device, and the oxygen sensitive material are a single unit. In a further embodiment of the present invention, a medical device comprising a polycarbonate composition is provided. The polycarbonate composition used in this embodiment of the present invention will visually indicate the presence of oxygen after being irradiated with gamma radiation.

In a method according to the present invention, an oxygen sensitive storage device is produced by placing an oxygen sensitive material inside a sealable container. The oxygen sensitive material can be any material that undergoes a visual change with oxygen after the oxygen sensitive material, or composition, has been irradiated with radiation. The atmospheric contents of the sealable container are then removed and the sealable container is sealed to isolate

the oxygen sensitive material inside the sealable container. The sealable container is then irradiated with an effective amount of radiation so that the oxygen sensitive material will undergo a visual change if the oxygen sensitive material contacts oxygen.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of one embodiment of a storage device where a container and an oxygen sensitive material are provided and where structures within the container have been made visible while hidden edges of the container are shown with phantom lines.

FIG. 2 is a side view of an oxygen sensitive material attached to a background material that enhances the visual change of the oxygen sensitive material.

FIG. 3 is a perspective view of one embodiment of the storage container of the present invention.

FIG. 4 is a side view of a resealable container that can be used in the present invention.

FIG. 5 is a side view of a foil pouch showing the plastic coating that can be heated to seal the foil pouch.

FIG. 6 is a top view of two distal occlusion inflation devices that contain a component piece comprising an oxygen sensitive material, with the right device having just been exposed to air and with the left device having been exposed to air for one week, to illustrate the color change associated with an oxygen sensitive material of the present invention.

FIG. 7 is a top view of two crimper devices that show a visual change associated with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In one embodiment of the present invention, a storage device is provided that comprises a sealable container adapted to isolate the contents of the sealable container from the ambient atmosphere. In this embodiment, an oxygen sensitive material is located inside the sealable container. The oxygen sensitive material can undergo a visual change upon contact with oxygen after the oxygen sensitive material has been irradiated with radiation in the absence of oxygen. In one embodiment, the visual change is a color change. In some embodiments, the sealable container can isolate a medical product from the ambient atmosphere, while in other embodiments the sealable container can isolate a food product. In one embodiment, the sealable container isolates a distal occlusion inflation device from the ambient atmosphere. In some embodiments, the oxygen sensitive material comprises a polycarbonate material. In one embodiment, the polycarbonate material comprises Dow Calibre™ polycarbonate material. In some embodiments, the sealable container is resealable, while in other embodiments the sealable container is not resealable. In some embodiments, the sealable container is substantially free of oxygen. In one embodiment, the sealable container is a foil pouch.

In another embodiment of the present invention, a medical device comprising a structural element is provided. The structural element comprises an oxygen sensitive polymeric material that can visually indicate if the medical device has been exposed to oxygen. In one embodiment, the medical device is a distal occlusion inflation device. In some embodiments, the polymeric material can visually indicate the presence of oxygen after the polymeric material has been irradiated by an effective amount of radiation. In one embodiment, the oxygen sensitive polymeric material comprises Dow Calibre™ 2081. In some embodiments, the radiation is

gamma radiation, while in other embodiments the radiation can be X-ray radiation. When the oxygen sensitive polymeric material comprises Dow Calibre™ 2081, an effective amount gamma radiation is from about 25 Kilograys to about 45 Kilograys. In some embodiments, the structural element is attached to a background material which enhances visibility of the visual indication of the presence of oxygen.

In another embodiment, a storage device comprising a sealable container and an oxygen sensitive material is provided. In this embodiment, the oxygen sensitive material will not function as an oxygen detector until the oxygen sensitive material has been activated. In some embodiments, the oxygen sensitive material can be activated by irradiating the oxygen sensitive material with radiation in an oxygen-free environment. In one embodiment, the oxygen sensitive material is activated by irradiating the material with gamma radiation.

FIG. 1 shows one embodiment of a storage device of the present invention. As shown in FIG. 1, a sealable container 101 isolates a product 103 from the ambient atmosphere 104. An oxygen sensitive material 102 is located inside the sealable container. The oxygen sensitive material, or composition, 102 can visually indicate the presence of oxygen inside the sealable container 101. In one embodiment, the visual indication of the presence of oxygen will be a change in color of the oxygen sensitive material. The oxygen sensitive material 102 of the present invention can be any material that will visually indicate the presence of oxygen after the oxygen sensitive material 102 has been irradiated by radiation. A suitable composition for the oxygen sensitive material 102 is a polycarbonate resin manufactured by Dow Chemical Company and sold under the trade name Calibre™ 2081. In one embodiment, when the oxygen sensitive material 102 comprises Dow Calibre™ 2081, the oxygen sensitive material will visually

indicate the presence of oxygen after being irradiated with gamma radiation. A suitable amount of gamma radiation has been found to be from about 25 Kilograys to about 45 Kilograys of radiation. In other embodiments, the radiation used can be X-ray radiation.

The oxygen sensitive material 102 can be formed into any desirable shape for use in the present invention. In one embodiment, the shape of the oxygen sensitive material is a rectangular chip. As shown in FIG. 2, the oxygen sensitive material 102 can be optionally attached to a background material 110 to enhance the visibility of the visual change of the oxygen sensitive material 102. The background material can be composed of metal, plastic, paper or any other suitable material that will enhance the visibility of the visual change. For example, a blue background material would make a yellow indicator appear green. Potential background materials could also have the word "exposed" written across the background material in a color such that upon contact with oxygen, the word "exposed" would become visible. In embodiments that employ a background material 110, the background material can be attached to the oxygen sensitive material 102 through the use of generally known adhesives or mechanical fasteners.

The sealable container 101 of the present invention can be composed of any substance that will transmit radiation and is impermeable to gas, especially oxygen. Examples of suitable materials for the container are metals, glass, gas impermeable plastics, gas impermeable thermosets and rubbers, and gas impermeable foil pouches. In one embodiment, the foil pouch is a multi-layer foil package comprising a silicone oxide treated PET layer, a foil layer, a biaxilally oriented nylon layer and a polyethylene layer. The gas impermeable plastic containers of the present invention can be either rigid or flexible. Suitable plastic materials include, but are not

limited to, gas impermeable polyethylenes, polystyrenes, polycarbonates, nylons and polyethylene terephthalates. Potential thermoset and rubber materials include gas impermeable phenol formaldehydes, urea formaldehydes, natural rubbers and nitrile rubbers.

As shown in FIG. 3, one embodiment of the sealable container 101 is a gas impermeable foil pouch 105 with a protective cardboard packaging 106. The sealable container 101 can be resealable or it can be a container that cannot be resealed. FIG. 4 shows one example of a resealable pouch 112 with closure means 114 on at least one end of the resealable pouch 112 that permits the resealable pouch 112 to be optionally resealed. The sealable container 101 of the present invention can be sealed by any conventional means known to be used in the packaging industries including thermal, adhesive, or airtight mechanical closures such as caps or lids. When the sealable container 101 is a gas impermeable foil pouch 105, a heat sealer can be used to heat plastic coatings located on the inside top and bottom of the foil pouch. FIG. 5 shows one embodiment of foil pouch 105 with plastic coatings 114 located on the inside top and bottom of the foil pouch 105. This heating causes the plastic coatings on the top and bottom to flow together and seal the foil pouch 105.

The product 102 contained within the sealable container 101 can be any product in which a controlled oxygen-free environment is desirable or necessary. Suitable products for the present invention include, but are not limited to, medical devices, pharmaceuticals and food products. In one embodiment of the present invention, the product 102 contained in the sealable container 101 is a distal occlusion inflation device.

In another embodiment, a storage device is provided that comprises a sealable container 101 and an oxygen sensitive material 102. In this embodiment, the oxygen sensitive material

102 will not function as an oxygen indicator until the oxygen sensitive material 102 has been activated. One method of activating the oxygen sensitive material 102 is irradiating the material with radiation. In some embodiments, suitable forms of radiation for activating the oxygen sensitive material 102 include gamma radiation and x-ray radiation. In one embodiment, the oxygen sensitive material 102 comprises Dow Calibre™ 2081 polycarbonate resin. When the oxygen sensitive material 102 comprises Dow Calibre™ 2081, a dose of gamma radiation from about 25 Kilograys to about 45 Kilograys of radiation will activate the material. While not wanting to be limited to a particular theory, it is believed that the oxygen sensitive properties of the Dow Calibre™ material is likely due to the dye used to color the plastic or the stabilizers used to protect the plastic from degradation.

In another embodiment of the present invention, a medical device contains a component piece that is composed of an oxygen sensitive polymeric material. FIG. 6 shows one possible embodiment where a GuardDog™ medical device 107 has a component piece that is composed of an oxygen sensitive polymeric material. The GuardDog™ 107 is a distal occlusion inflation device which uses CO^2 as the inflation medium which generally comprises a main body 108 and a crimper device 109. In this embodiment, the crimper device 109 and the main body 108 are composed of an oxygen sensitive polymeric material. One reason for using an oxygen sensitive indicator material in this application is because the inflation medium needs to be relatively free from oxygen in order to prevent the release of oxygen or ambient air into the blood stream in the event that the distal occlusion inflation device would burst thereby causing a potential embolism. By using CO^2 as the inflation medium, the inflation gas can be easily absorbed into the blood stream in the event that the inflation device fails. The oxygen sensitive indicator material

permits the operator to confirm that the gas within the device that will be used to inflate the inflation device does not include any significant amount of oxygen prior to the use of the device.

In one embodiment, the oxygen sensitive polymeric material is composed of Dow Calibre™ 2081 polycarbonate resin. When a medical device with an oxygen sensitive polymeric component piece comprising of Dow Calibre™ 2081 is irradiated with gamma radiation, in the absence of oxygen, the oxygen sensitive material becomes activated and will undergo a visual change if oxygen contacts the material. In one embodiment, the visual change, or indication, is a color change. It has been found that from about 25 Kilograys to about 45 Kilograys of gamma radiation will activate Dow Calibre™ 2081.

An example of the visual change, which indicates the presence of oxygen, associated with this embodiment of present invention can be seen in FIG. 6 by comparing the color of the crimper device 109 on the left of the Figure with the color of the crimper device 109 on the right of the Figure. The elapsed time, after exposure to oxygen, before a visible change can be detected is generally 1-8 hours, preferably 1-2 hours. As shown in FIG. 6, when a component piece of a medical device is composed of an oxygen sensitive polymeric material, the device itself becomes an oxygen indicator, and any ambiguity about whether the device has been exposed to oxygen is removed.

The method for producing the storage device of the present invention involves placing an oxygen sensitive material 102, for example, Dow Calibre™ 2081 polycarbonate resin, inside a gas impermeable sealable container 101. In some embodiments, a product 103, such as, for example, a medical device or food product, will also be placed into the sealable container 101. In one embodiment, the sealable container 101 is a foil pouch. As discussed above, the oxygen

sensitive material 101 can be any material that visually indicates the presence of oxygen after exposure to radiation. As discussed above, the oxygen sensitive material 102 can comprise a polycarbonate resin. Furthermore, the oxygen sensitive material may be formed into any desired shape or size depending upon the application.

Before being placed inside the sealable container, the oxygen sensitive material 101 can optionally be attached to a background material 110 to enhance the visibility of the visual change. In addition, the oxygen sensitive material 101, and the optional background material 110, can be either fixed inside the container or can be free moving inside the container. By fixed inside the sealable container 101, it is meant that the oxygen sensitive material 102 is directly attached to the inside of the sealable container 101. In embodiments where the oxygen sensitive material is fixed inside the sealable container 101, any conventional method of attachment, including adhesives and mechanical fasteners, may be used that do not interfere with the function of the oxygen sensitive material 102. Conversely, the phrase "free moving" is intended to describe embodiments of the present invention where the oxygen sensitive material 102 is not attached directly to the inside of the sealable container 101.

The atmospheric contents of the sealable container 101 are then removed by either vacuum or by purging the sealable container 101 with a inert gas such as nitrogen, carbon dioxide, argon or helium. In one embodiment, a vacuum is used to remove the atmospheric contents because a higher percent of oxygen, or atmospheric gas, can be removed in a shorter period of time as compared to purging. If the atmospheric contents of the container are removed by a vacuum, the sealable container 101 may be subsequently filled with an inert gas. In some embodiments, the ability of the oxygen sensitive materials 102 to visually indicate the presence

of oxygen is not dependent upon the choice of inert gas used as the controlled environment. Furthermore, the oxygen sensitive materials 102 of the present invention can also function in applications where the controlled environment is a vacuum.

Once the atmospheric contents have been removed from the sealable container 101, the sealable container 101 will be substantially-free of oxygen. As described above, the sealable container 101 can be filled with a substantially oxygen-free gas. The substantially oxygen-free gas can be nitrogen, helium, argon, carbon dioxide or some other inert gas. In some embodiments, the sealable container 101 is not filled with a substantially oxygen-free gas, and in those embodiments the controlled inert environment is a vacuum. The sealable container 101 is then sealed to isolate the oxygen sensitive material 102 from the ambient atmosphere. As noted above, the sealable container 101 may be sealed by any conventional means known in the packaging industry including, but not limited to, thermal, adhesive or mechanical closures. In embodiments where the sealable container 101 is a foil pouch 105, a heat press can be used to seal the foil pouch. The choice of sealing means will generally be determined by the particular choice of container being employed in a specific application.

The sealed container, including any contents or products contained within the sealed container, can then be irradiated with an effective amount of radiation to activate the oxygen sensitive material 102. As discussed above, the sealable container can isolate food, medical device, pharmaceutical or other products from the ambient atmosphere. In some embodiments, the radiation used to activate the oxygen sensitive material 102 is gamma radiation. In other embodiments of the present invention, the radiation used to activate the oxygen sensitive material is X-ray radiation. In one embodiment, where the oxygen sensitive material comprises

Dow Calibre™ 2081, an effective amount of gamma radiation to activate the oxygen sensitive material has been found to be from about 25 Kilograys to about 45 Kilograys of radiation.

In the embodiment of the present invention where the oxygen sensitive material 102 is Dow Calibre™ 2081, the gamma radiation can visually change the oxygen sensitive material 102 from a purple color to a yellow gray color. In this embodiment, once this color change has occurred the oxygen sensitive material 102 has been activated. Once activated, the Dow Calibre™ 2081 material will undergo a visual color change when exposed to oxygen. Prior to being activated, some of the oxygen sensitive materials 102 of the present invention will not undergo a visual change when exposed to oxygen. As a result, some of the un-activated oxygen sensitive materials of the present invention can be handled and stored in oxygen rich environments. This feature of the oxygen sensitive materials of the present invention facilitates easier storage and processing of the sensor materials as compared to other chemical oxygen indicators. FIG. 7 shows one example of a visual change associated with one embodiment of the present invention where the oxygen sensitive material comprises of Dow Calibre™ 2081. The device on the left side of FIG. 7 has been exposed to oxygen for 1 week, while the device on the right side of FIG. 7 has just been removed from a substantially oxygen-free environment.

The embodiments are intended to be illustrative and not limiting. Additional embodiments are within the claims. Although the present invention has been described with reference to particular embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and the scope of the invention.